SOLAR MAGNETIC DRIVERS OF SPACE WEATHER

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LONG-TERM GOAL

Our major goal is to improve the accuracy and timeliness of solar magnetic field data that are used to predict space weather disturbances that affect Earth.

SCIENTIFIC OBJECTIVES

The primary objectives are to provide best estimates of the magnetic flux distribution along the central meridian of the sun as a function of time and also best estimates of the magnetic flux over the entire surface of the sun at specified instants of time. These data are required as boundary conditions for numerical models that are used to predict space weather conditions. Our secondary objectives are to explore poorly understood aspects of the solar magnetic field that may have future significance in understanding space weather. The specific targets are the polar magnetic field, the intranetwork magnetic field, and field configurations associated with coronal mass ejections.

APPROACH

To improve the central meridian synoptic data, we will develop new algorithms and computer codes to replace 25-year-old programs that have known defects. The new code will allow prompt inclusion of the most recent data instead of waiting until the end of one complete solar rotation as with the old code. It will also convert the measured line-of-sight component of the magnetic field to magnetic flux density estimates. The data will be provided to modelers of space weather via the Internet and to everyone by means of a web page. To provide a flux estimate of the entire surface of the sun at a specified time, we will write new codes that allow for differential rotation of the sun and evolution of magnetic structures. These data will also be provided to users via a web page interface. The major challenge here is to gain a sufficient understanding of the evolution of magnetic fields to reliably interpolate and extrapolate to times when observations are not available.

Exploration of the polar magnetic field will be done by studying our 25-year-long data base of daily observations. The main effort will be to measure the systematic tilt of the magnetic flux near the pole as a function of latitude so that accurate conversion to flux can be made. We will also use the unique measurements of the chromospheric magnetic field to study the characteristics of the polar magnetic field as a function of height. A study of the intranetwork magnetic field will again use the long data base to investigate whether this field component

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exhibits solar cycle and latitude variations. The study of patterns associated with coronal mass ejections will center on comparing these events with underlying magnetic features and their changes. The participants in this work are the PI and Co-PI, and post-doctoral research associate Dr. John Worden.

WORK COMPLETED

We successfully transitioned from the previous grant which had a strong theoretical emphasis and a larger budget to the present effort which is data oriented at a lower budget level. The PI and Co-PI exchanged roles with the start of the present grant. A new post-doctoral research associate was recruited and hired in May, 1997. During the subsequent four months we have developed and tested new code to produce the central-meridian synoptic maps and some new data products. The calibration of magnetic flux has come into question and has been investigated. The basic logic for the whole-sun flux maps has been worked out. Working relations have been established with the modelers that use the data. We organized and participated in an international workshop on the general topic of "Synoptic Solar Physics" (1998). A paper on some of the work supported by this grant was submitted (Harvey and Worden, 1997).

We provided polar field data for a published investigation of its association with streams of mass emitted from the polar regions (Wang et al., 1997). We recently obtained several special observations of the chromospheric component of the polar magnetic field. Sources of noise were located in the observing equipment. Fixing these noise sources will allow us to significantly improve our observations of the intranetwork magnetic field. The PI attended a workshop on coronal mass ejections to help develop information about magnetic associations of these events.

RESULTS

The new central-meridian flux maps are superior to existing products in quantitative accuracy, geometrical fidelity, and correction to flux. A high spatial resolution version of the map is a new product that is very useful in comparing with similar maps of solar activity. A preliminary comparison of some of our data with coronal measurements from the Yohkoh and SOHO spacecraft clearly show strong associations. For example, magnetic islands of one polarity are associated with "fountain" or "anemone" coronal loop patterns. Small x-ray emitting features seem to prefer locations where the magnetic polarity reverses. Locations of coronal mass ejections have tended to be fixed at places where the magnetic neutral line has a distinct "switch back" pattern. In studying the evolution of magnetic flux eruptions, we were surprised to find that some features erupt and disappear in one solar rotation without leaving a trace while others leave remnants that endure for months.

Our polar field studies indicate that the field is systematically tilted away from the pole by a few degrees. The decay of the polar flux with time has been very slow during the past several years of quiet solar activity; it is now accelerating with the rise of new solar activity. Dense streams of mass flowing outward from the poles appear to be associated with bipolar features in the otherwise unipolar flux pattern.

IMPACT/APPLICATION

The new central meridian magnetic flux maps will allow more accurate modeling and prediction of space weather. In particular, the high accuracy of the polar fields is a significant step forward

that will allow better prediction of the solar wind speed near Earth at times of low solar activity. A quantitative check of the quality of the predictions will be possible away from the ecliptic plane by comparing with measurements from the Ulysses spacecraft. We anticipate that the forthcoming maps that will be updated daily will allow the first steps at predicting the arrival of coronal mass ejections at Earth. If our preliminary results that such ejections are associated with recognizable magnetic patterns hold up, we should be able to predict times of higher or lower probability of space weather disturbances at Earth.

TRANSITIONS

Our data are being used as inputs to numerical models by the NRL Solar Physics Branch (Code 7660, Wang and Sheeley), the Air Force Phillips Lab (Space Effects Division, Kahler and Webb), NOAA Space Environment Center (Rapid Prototyping Center, Arge and Pizzo), and the SAIC Applied Physics Operation (Solar Physics Group, Linker and Mikic). In addition, the data are used by dozens of observatories and researchers around the world for basic solar physics investigations.

RELATED PROJECTS

We are working closely with Nick Arge and Vic Pizzo at NOAA (who are supported by an SR ONR grant) to ensure that our new data products are what is needed for their real-time prediction work. Similarly, we have been in contact with Todd Hoeksema (Stanford, Wilcox Solar Observatory) who is also producing data similar to ours under an SR ONR grant to be sure that systematic errors in one or the other data sets are located and eliminated. We have also been trying to standardize the format of various data products.

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WEB ADDRESS

http://argo.tuc.noao.edu:2001/synoptic.html/. This page shows the latest observations that are available from NSO Kitt Peak.

http://argo.tuc.noao.edu:2001/maps.html/. This page allows access to the synoptic map data (under construction).